P. W. WEBER

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the joint supervision of the
UNIVERSITY OF HAWAII
AND THE
UNITED STATES DEPARTMENT OF AGRICULTURE

CIRCULAR NO. 13

NURSERY PROPAGATION AND TOPWORKING OF THE MACADAMIA

By

J. H. BEAUMONT, Principal Horticulturist
And
RALPH H. MOLTZAU, Principal Scientific Aide

Issued December, 1937

Published by the
University of Hawaii
Honolulu, T. H.

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J. H. BEAUMONT, *Principal Horticulturist,*
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INTRODUCTION

The culture of the macadamia is a young and promising new industry in the Territory of Hawaii. In common with all other plants in which man develops an active interest, this plant seems destined to undergo many changes to adapt it to a greater and more profitable utilization. The accumulated knowledge of the improvements that have taken place in other similar plants should serve as a useful guide to, and in part, forecast the probable future developments that may be anticipated. With this information, also, many of the costly mistakes invariably experienced in producing a new crop may, in part, be avoided.

Fruit and nut trees require a long time to reach maturity and only a few can be grown per acre; consequently, great value and importance should be attached to each tree. When planted, the grower should have a reasonable expectancy as to the future performance of the tree. This can best be attained when definite varieties of known performance abilities are planted.

The macadamia does not breed true from seed except as to type or species, of which there are two that are grown commercially in the Territory, the so-called rough-shell (*Macadamia ternifolia*) and smooth-shell (*M. ternifolia* var. *integrifolia*) types. For convenience and also to avoid confusion with the term "horticultural variety," it seems desirable to designate the species and its botanical variety as "types." The term variety is used in this publication to designate a group of plants that have been propagated asexually from a single individual of one or the other type. In planting the seedling tree of one or the other type, therefore, the grower may expect only that the trees will be of

that type. Within the type will be a wide range of variation in both tree and seed characters, many of which will be definitely inferior, while some may be definitely superior. The present seedling groves in the Territory provide an excellent opportunity to select the superior plants. This is being done, and after they have been propagated and tested they will be introduced as varieties. Of equal importance, however, are the problems, first, of developing ways and means of perpetuating and multiplying the more desirable trees and second, of improving the average quality, grade, and yield of the bearing seedling groves by topworking.

In view of the increasing interest in new plantings of macadamia and the rather important problem of bringing the present seedling groves into greater production, it seems advisable to present some of the principles and methods that seem best adapted to the propagation and topworking of this plant, even though time has not been available to work out and test them in detail.

NURSERY PROPAGATION

The macadamia is rather an unusual plant and is difficult to work with in many ways. Because of its wood and bark structures and habit of growth, some of the more useful methods of propagation by grafting cannot be applied successfully. Of the various means of propagating plants, the side-wedge and side-paste methods of grafting seem best adapted. Budding is extremely difficult, if not impossible; the whip graft does not seem satisfactory; and other means of multiplying a plant such as by cuttings and layering are tedious and expensive. For these reasons, only propagation by means of the side-wedge and side-paste methods will be considered.

Source of Seed

The first step in the nursery propagation of the macadamia is to obtain the seed and grow the seedlings on which to graft. Two choices of seed are possible: seed of the rough-shell or of the smooth-shell types. Investigations are in progress to determine which of these makes the better rootstock, but at present no definite recommendations can be made. Scions of the smooth-shell type may be grafted successfully on rough-shell type stocks, but it is unknown whether this combination will make a long-lived, thrifty tree. For the present, therefore, it is suggested that smooth-

shell stocks be used to graft smooth-shell varieties and rough-shell stocks for rough-shell varieties.

The source of seed, so far as is known, need be of little or no concern, provided the seed is fresh, well matured, and capable of good germination. Large seeds are not necessarily to be preferred, inasmuch as there are fewer per pound or per bushel than those of medium or small sizes, the number of seedlings is the chief consideration, and it has not been proved that more vigorous seedlings will be produced from large seed. If possible, it would seem logical to select from large vigorous trees on the assumption that seedlings of such trees would tend to reproduce the parent form.

Time of Planting

Several advantages are gained by planting seed in the late fall or early spring. The normally greater winter rainfall reduces the amount of artificial irrigation necessary, cloudy weather reduces the likelihood of sunburn of the small tender seedlings, and good germination and rapid growth are obtained in time for any necessary transplanting before the hot, dry weather of summer. A full year of growth is provided, and a strong vigorous plant most suitable for grafting will be produced.

A fine, thoroughly washed coral sand is satisfactory for germinating seed in sand boxes. The sand should be well drained and at least 12 or 14 inches deep, in order to permit full extension of the taproot. The seed should be planted about 2 inches deep and 1 to 1½ inches apart. Good germination usually occurs in from 1 to 2 months if the seed is kept continually moist and the sand box is in a warm, partially shaded location. If the seed has been allowed to dry out before planting, germination is often increased by soaking it in water for about 48 hours.

The advantages of the sand box are that more careful attention to and accurate regulation of conditions bringing about good germination are possible. An opportunity to force the seedlings and finally to eliminate poor seedlings at time of transplanting is afforded. Transplanting may induce the formation of a better root system than if the seedling is grown in place in the nursery row.

The seed may be planted directly in the nursery row if conditions are favorable. A deep well-drained, friable soil, free from weeds, deeply plowed and thoroughly prepared,

should be used, and provision for irrigation must be made. Space the rows from 2½ to 3 feet apart to permit working around the plants and to allow using horse or power cultivation. The seed should be planted 2 inches deep and from 2 to 3 inches apart. It should be kept continually moist during germination. Excellent success has been obtained at Kona, Hawaii, and at Kailua, Oahu, using these methods. Stands may be somewhat more irregular than if the seedlings are transplanted, and weeding, cultivation, and irrigation may be somewhat more difficult, but good sturdy plants are usually produced at no risk of dying or of retarding their growth through transplanting.

TRANSPLANTING

When the seedlings in the sand box are from 4 to 6 inches high and have slowed down in growth, they are ready for transplanting. Select a deep, friable, and fertile soil, and prepare it thoroughly in advance. Open a fresh furrow from 8 to 10 inches deep, in which to plant the seedlings, and arrange for the planting to take place immediately so that the soil will not dry out. Transplanting should not be done during hot, drying weather.

Seedlings should be dug immediately before transplanting. The culls should be thrown out. The roots of the others should be pruned or trimmed as much as seems necessary. The taproot should be cut back to 6 or 7 inches in length. For convenience in handling, the lateral roots may be trimmed off if they are found to be long and stringy. It is usually not necessary to cut back the tops. Space the seedlings from 6 to 8 inches apart and plant them 1 or 2 inches deeper than they were in the sand box. The lateral roots should be well distributed, and the soil should be well firmed around them. Until the seedlings become well established, frequent light irrigations should be given. Thereafter, irrigation may be less frequent. Ammonium sulphate or sodium nitrate, should be applied lightly at intervals of 6 weeks or 2 months, to force the seedlings as much as possible. The first application may be made from 3 to 6 weeks after transplanting. During the 2 or 3 months preceding grafting, nitrogen should be withheld, to retard growth and to permit the stocks to accumulate carbohydrates and other storage materials. Immediately after grafting, a nitrogen application, irrigation, and thorough cultivation should again force the trees into active growth.

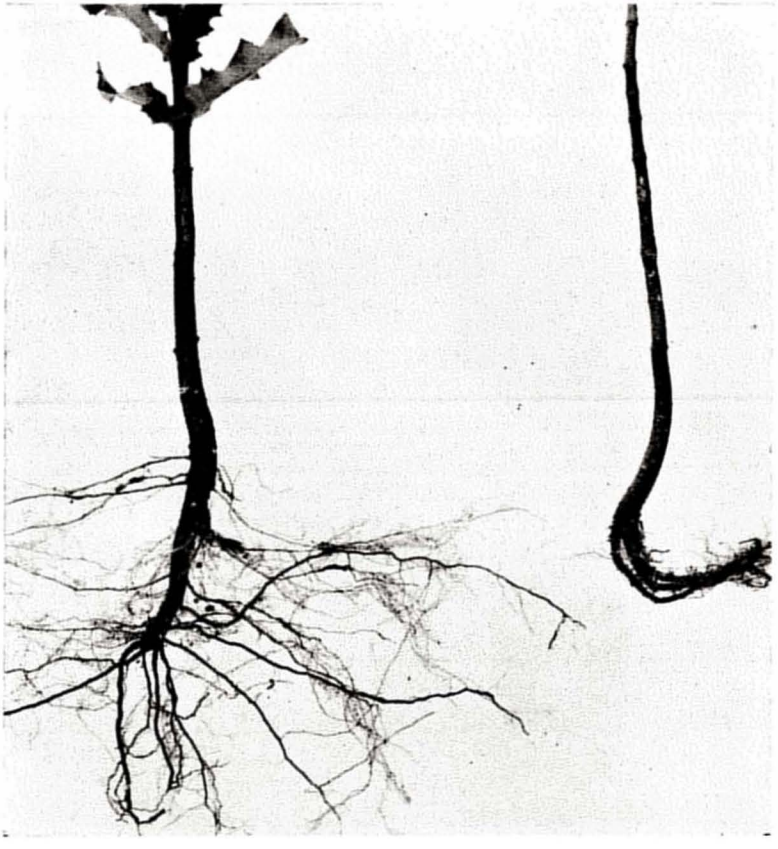

Figure 1—The effect of growing macadamia seedlings in soil and in cans. The tree to the right was grown in an 18 oz. can, and is one year older than the plant to the left. The fibrous roots have been trimmed off to show the position and behavior of the taproot and main lateral roots. The tree to the left was transplanted in a good nursery soil. Note the large and well-distributed root system. Such a seedling should produce a strong well-anchored tree after transplanting. The seedling on the right may produce a tree similar to that in Figure 2; its lateral root is curved and developed only on one side, resulting in poor anchorage, often the case with trees grown in cans. (1/5 natural size).

Macadamia seedlings grown in cans or pots become "root bound," a condition which they seldom outgrow. Such trees may blow over easily and usually require bracing. Much of the early slow growth and irregularity of trees in the grove may also be traced to this cause. Figure 1 illustrates the advantages possessed by seedlings grown in soil over seedlings grown in tins.

GRAFTING AND GROWING TREES

One of the basic principles of all methods of grafting is to bring the cambium tissues of the stock and scion into closest proximity so that they may grow together and establish a continuous conductive system between the root and the growing points of the scion. The cambium is a very thin layer of cells lying between the wood or xylem and the inner phloem of the bark. By cell division, this layer of cells gives rise to other cells, those on the inside differentiating into wood cells and those on the outside differentiating into new phloem cells. These new cells form the conductive system through which moisture and nutrients are translocated throughout the plant, and it is only in this way that successful graft unions are formed.

Under tropical conditions, it might be assumed that grafting can be done at any season of the year, provided the stocks and scions are in suitable condition. However, it is found that many plants have striking seasonal behavior, such as dropping the leaves and definite periods of blossoming and fruiting. Other plants are much less cyclic in behavior. Among the latter may be classed the macadamia, litchi, and mango. These plants may grow and bloom at any season. Thus the macadamia may bloom and bear fruit throughout the year and may never store up large quantities of food reserves in the fruiting branches and new growth. These conditions seem to be intimately related to the problem of asexual propagation, for it has been determined that, unless a considerable amount of starch is found in the stock and scion, the graft will probably not be successful.*

The season of greatest relative dormancy of the macadamia in Hawaii occurs between October and February.

*W. W. Jones, Hawaii Agricultural Experiment Station, is responsible for the discovery of this relationship and its application to propagation. A detailed report of the work is in preparation.

Figure 2—A 10-year-old seedling tree blown over at the beginning of its period of greatest productivity. While it had a good taproot, the lateral roots have arisen on one side only, a condition common to most trees grown in cans and where the roots have not been stimulated to lateral growth through the use of proper root pruning.

The larger part of the crop will have been harvested and the main period of bloom will not have been reached. Cooler temperatures at this season presumably retard growth and flowering and are favorable for carbohydrate storage. In the wood and pith of branches suitable for scion wood, starch is found in greatest abundance at this period, while later, during growth and blooming, the starch rapidly disappears.

Carbohydrate storage in the scion may be increased by ringing the branch below the point where the scion normally would be cut. The ringing should be done just as though an air-layer were to be made, i.e., a ring of bark one-half inch or more wide should be cut away and the wood scraped to remove remnants of the phloem or inner bark and cambium, without injuring or cutting into the wood more than is necessary. The sugar produced by the leaves on the scion wood cannot flow to the main body of the tree and is stored as starch above the ring. Ringing also retards movement of water to the scion, and this, together with the high carbohydrate condition of the scion, prevents active growth and utilization of the stored materials. When the ringing is done 2 or 3 weeks before the scions are to be cut and used in grafting, an abundance of starch accumulates in the portion of the stem above the ring.

The stocks should also be high in reserve carbohydrate. It has been previously suggested that the stocks be forced early in their growth but retarded by withholding nitrogen during the last 2 or 3 months before they are to be grafted. If possible, water should also be withheld during the last 4 to 6 weeks to prevent active growth and to permit accumulation of food reserves in the body of the tree. Just before or during grafting, the stocks should be fertilized with a quickly available nitrogen fertilizer. They should be irrigated and cultivated so that they will immediately start into active growth. Figure 3 illustrates varying amounts of starch stored in the wood and pith of seedlings at different periods of growth. The black spots represent starch granules stained with an iodine solution. The number and size of granules in Figure 3 *c*, indicate a high concentration. High percentages of successful grafts have been secured when the stocks and scions both show an abundance of starch storage.

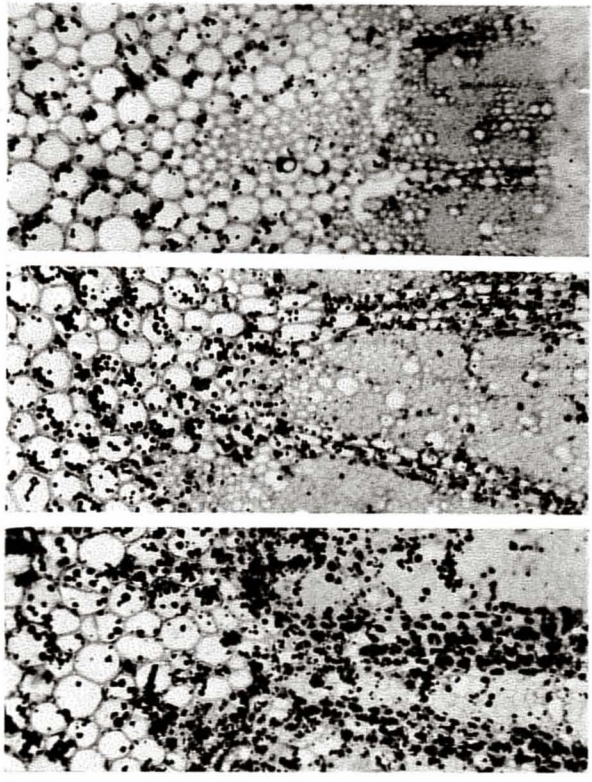

Figure 3—Varying degrees of carbohydrate storage in direct relationship to the treatment given the seedlings from which the sections were taken. The black dots in the pith and xylem represent starch grains. *a*, shows very light storage; *b*, medium storage; and *c*, heavy storage. Abundant starch storage in both scion and stock is conducive to formation of a graft union and rapid growth of the scion.

Selecting Scion Wood

Branches of selected trees one-half inch or more in diameter on which is found a quantity of terminal growth suitable for cutting into scions may be ringed. Two weeks later the branch should be cut off at the ring and the terminal wood cut up into scions, from 3 to 4 inches in length and from $^{3}/_{16}$ to $^{4}/_{16}$ inches in diameter. These should have 2 or 3 nodes or whorls of buds. The leaves should be cut off with a sharp knife, not torn off. The latter procedure may tear the bark and will leave large wounds which permit evaporation of moisture from the scion and which may favor the entrance of disease organisms. Long willowy growth or wood that is producing new leaves or blossoms or that is carrying a cluster of fruits should not be used. Such wood is not dormant and is likely to be depleted in food reserves.

It may be necessary to ship scions from various places in the Territory to the nursery where they will be used in grafting, or to hold them for several days until they can be used. The importance of careful handling and packing of the scions can not be overemphasized, for it has been observed repeatedly that scions quickly lose their vitality. Dipping the cut ends in warm paraffin, packing the scions in moist sphagnum moss, wrapping them in water-proof paper and storing them in a cool, moist place, will keep the scions in good condition for several days. When working in the field, carry only a small quantity of scions and keep them in a moist piece of burlap or other suitable material to keep them fresh. Greatest speed in removing the scion from the tree and grafting it in place on the stock is essential. Scions in a fresh, turgid condition and with good food reserves should give a high percentage of "takes" if the stocks are in the proper condition.

Grafting Operations

Immediately before beginning grafting operations, the operator should trim the lower leaves and any low lateral branches from the stocks for a distance of 6 or 8 inches above the ground. The soil should be hoed away from the rows, thus exposing as much of the trunks as possible without disturbing the roots. These two operations will greatly facilitate grafting and tying and will permit the operator to

make the graft on the thicker portion of the stock near the crown of the seedling.

Side-wedge method: The side-wedge method of grafting consists of inserting a scion, sharpened to a V or wedge shape at the basal end, into an oblique cut in the stock, the stock being bent over to permit entry of the wedge and holding it in place when pressure on the top is released. The stock is prepared first by making a straight downward cut into the trunk at an angle of about 30 degrees. The cut should not extend past the center of the stock and may be from ¾ to 1 inch in length. The top of the stock may be gently pushed over to aid in making the cut, but care must be taken that the stock does not split. When small seedlings are used, the cut is made as close to the ground as possible, at the same time allowing sufficient room for tying and waxing. With stocks of larger diameter, the cut may be made somewhat higher. It is desirable, however, to make the graft as low as possible, so that the crook or bend that always results from a graft will be at or below the surface of the soil when the tree is transplated to the field.

Then the scion should be prepared. Select a scion with at least 3 nodes and of the same diameter or slightly less than that of the stock to be used. The top of the scion should be pruned back to within ¼ or ⅜ inch of the upper node and the basal end should be trimmed in the form of a V-shaped wedge, the upper edge of the cuts starting at or immediately below the lower node. The cut surfaces should match those of the stock as closely as possible. It is imperative that all cut surfaces be perfectly flat and smooth in order that they may fit closely together.

The scion should be inserted into the stock. By grasping the stock in the left hand and gently bending it, the operator may open the cut enough to permit entry of the scion. The scion should be forced firmly into place in the open cut with the right hand. The cambium layers of the stock and scion should be adjacent for as great a distance as possible. When the pressure of the left hand is released, the stock should spring back into place and hold the scion so firmly in place that it will resist mild pressures in attempting to move it. Figure 4*a* illustrates a properly made side-wedge graft. Note that the cut in the stock has not been made so deeply as to greatly weaken the stock to the point where it would blow over easily or would not spring back and hold

(*a*) (*b*)

Figure 4—(*a*) Properly made side-wedge graft; (*b*) Successful graft three months after operation and just before the top of the stock is cut back to the upper point of union.

the scion firmly in place. Note also the straight cuts and close contact between the stock and scion, particularly on the inner surfaces.

After the scion has been inserted it should be tied firmly in place. Raffia, string, tape, or similar materials may be used, the objective being to hold and protect the graft until a union is formed. The scion and the exposed cut surfaces of the stock should then be coated with a low-melting-point paraffin or soft wax to prevent the drying out and death of the scion and the possible entrance of disease organisms. Tying and waxing must follow the grafting immediately.

Side-paste method: The side-paste graft employs the same principles as the side-wedge graft and differs mainly in technique.

The stock should be prepared in much the same manner as with the side-wedge except that it is not cut so deeply and the outer tongue of wood and bark is cut off. A flat surface, notched at the bottom and composed of the wood, cambium, and bark, is exposed.

A scion of almost identical diameter as the stock must be selected and cut to match the cut surface of the stock. The cut surface of the scion should be placed against the cut surface of the stock, so that the cambium tissues of the two coincide to the greatest extent possible. If the surfaces do not match closely or if either is irregular or rough, preventing a close fit, new surfaces should be cut.

Tying and waxing should follow the grafting immediately as described under the side-wedge method. However, when the side-paste method is used, tying requires somewhat more care and skill. The scion must not only be held in perfect alignment with the stock during the tying, but also as great pressure as possible must be applied to insure a close contact of the stock and scion. This is sometimes difficult, especially when small stocks are used.

Treatment after grafting: Immediately after grafting, the terminal portion of the seedling stock should be headed back, leaving a number of large, well-formed leaves. This practice retards the formation of new shoots and the utilization of the reserves of the stock in shoot growth, and it also increases root-top ratio, thus insuring a surplus of moisture to the graft. This tends to induce callusing and union of the stock and scion.

After the scion has made from 4 to 6 inches of growth, the entire seedling top should be removed at a point immediately above the graft union. The wound should be painted or coated with wax to insure rapid healing and to prevent decay. Figure 5 is a close-up view of a row of seedling stocks properly grafted, tied, and waxed, and Figure 4*b* illustrates a successful graft 3 months after the operation and ready for the removal of the seedling top.

Growing Nursery Trees

After the grafts have started to grow, they should be given good cultivation, fertilization, and irrigation, in order to produce as large a tree as possible during the growing season. It may be necessary to stake and tie the young tender shoots to prevent wind from breaking them. The young plants must be watched carefully and trained to a single stem by pinching or cutting off lateral branches and removing the weaker of the shoots arising from the scion. With well-grown stocks, good soil, and careful cultivation, it is possible to grow a 3 or 4 foot tree in one growing season from the time of grafting.

Digging and Handling

When trees are grown in soil in the nursery, much greater care in digging and transplanting will be required than when they are grown in cans or tubs. The greater vigor, better root system, and other advantages of the nursery-grown tree, however, will more than justify the labor and care necessary. Under no conditions should the trees be moved during or immediately after a flush of growth. The time between digging and transplanting must be as short as possible, and the location in which the trees are to be planted should have been thoroughly prepared to receive the trees. The rainy season is best for digging and transplanting. It may be necessary to move the trees in a ball of soil bound with burlap, especially if they can not be planted immediately. Preliminary trials in transplanting indicate that this laborious process is not necessary if the trees are handled quickly and the roots at no time are allowed to dry out.

Digging is usually accomplished more easily and quickly if a furrow or trench a foot or more deep is dug along one side of and about one foot from the row of trees. Two men,

Figure 5—One year old nursery-grown seedlings that have been grafted, tied, and waxed.

working on opposite sides of the row, should make a good digging team. The first, working in the trench, should dig under the plant and cut the tap root and other deeply penetrating roots. The second man, working on the opposite side, should drive his spade straight down into the soil about 1 foot from the plant, thus cutting most of the lateral roots on his side. Then he should pry or lift the plant toward the trench. The first man should grasp the trunk of the tree and lift it out, while the second cuts other roots that still may be holding. The tree must not be jerked out, for jerking will break and tear off many roots. After it is dug up, it should be carried immediately to the packing shed or, if a large number are being dug, they may be "heeled in" by laying them down in a furrow and covering them with loose, moist earth. Later they may be carried to the shed for packing.

For shipment, the trees should be tied in small bundles, preferably of 5 trees each, with an abundance of moist sphagnum moss among the roots, to prevent drying out or molding. Several of these bundles should be tied together to form larger packages suitable for shipment, moist sphagnum moss again being used, and the whole wrapped first in moisture-proof paper and finally in strong craft paper and burlap.

Planting

Upon receipt, the bundles should be opened, inspected, and given such care as seems advisable under the circumstances. If they are to be planted immediately, the bundles need only be loosened and the moss moistened. If planting is delayed unavoidably, separate the trees and heel them in. Select a cool, shady location, dig a trench, place the trees in it, and cover the roots and greater portion of the tops with moist earth. When ready to plant them in the field, have a barrel of water or thick, pasty mud on a wagon or stone boat in which the trees can be carried to the field and kept until actually planted. Grafted trees ready for orchard planting are shown in Figure 6.

The holes should be freshly dug, so that the soil will be moist, 1½ to 2 feet deep, and at least 2 feet in diameter. The surface soil, which is more fertile and friable, and which should be filled around the roots in planting the tree, may be thrown to one side for this purpose and the subsoil

(*a*) (*b*)

Figure 6—Grafted trees ready for orchard planting, showing (*a*) properly trained to the leader type and (*b*) a tree with two verticals near the top, one of which should be pruned off or "headed back."

to another. The depth of the hole is determined by the depth and spread of the root system. In judging the depth of planting, a good rule to follow is to plant the tree so that the graft union will be at or immediately below the surface of the soil, provided, of course, that the graft was made properly.

In planting, throw out all dried soil and set the tree in place so that the depth of the hole may be judged relative to the tree. If the hole is too deep, fill in moist surface soil and tramp it down firmly until the hole is the proper depth with the tree resting on the bottom. Be sure that the tree is in proper alignment with other trees or line stakes and carefully fill the hole about one-third full with moist topsoil. meanwhile holding the tree in place but shaking it up and down to permit the soil to settle around and among the roots. After again checking the alignment, the planter should then get into the hole with both feet and tramp the soil firmly as each additional shovelful is thrown in until the hole is completely filled.

Irrigation immediately after planting and at frequent intervals thereafter is essential until the trees become established. Windshields, or bundles of grass tied around the trunks and lower limbs, may be necessary to prevent drying out and wilting of the trees in windy and dry locations. If, however, the trees are dormant and transplanting is done during the rainy and cooler season of the year, very few trees should be lost.

After the trees have become established in their permanent locations, they will not require close supervision. The orchardist should realize, however, that the more quickly a large tree can be grown, the earlier it is likely to bear large crops. Irrigation, cultivation, fertilization, early training, and pruning will be the subjects of later papers.

TOPWORKING

The seedling groves of macadamia present a real problem in that many of the trees are distinctly inferior not only in growth habit and yield but also in nut characters, such as size, thickness of shell, and quality of kernel. In fact, many trees are a distinct liability in the grove, rather than an asset. To improve these trees would improve the average of the entire grove. They should be replanted with a good quality variety or they should be topworked. Realizing the importance of this problem, we conducted experiments

to find the methods best adapted to topworking the macadamia, which, if successful, would yield quicker returns than replanting. The cleft, bark, inlay, and side-wedge grafts in the trunk and main limbs of topped trees were all given thorough trials. While all gave a few "takes," the topping and immediate grafting of old bearing trees do not now seem practical under most conditions. Other methods have been developed or adapted to the macadamia and seem to be completely successful.

Selecting Trees to be Topworked

The first step in topworking is to carefully appraise the trees in the grove from the standpoint of yielding ability, type of tree, disease resistance, and other factors, especially the size and thickness of shell of the nut. This can be done only by carefully inspecting each individual tree, cracking a sample of nuts, and arriving at a decision regarding it. Incidentally the grower may, at the same time, select the best of the trees and propagate from them rather than from trees belonging to other growers. The trees to be topworked may be blazed above the point of grafting, or otherwise marked in a conspicuous manner. Only definitely inferior trees should be topworked at first, because the major purpose of the process is to bring the least desirable trees into profitable production. Later, as more information on the behavior of different varieties becomes available, other trees might be topworked.

In rough-shell seedling groves, the percentage of trees to be topworked might be larger, inasmuch as experience has shown that seedlings of this type of nut are on the average inferior to those of the smooth-shell type. However, the work should be done over a period of several years and not attempted all in one year. Here again, the trees should be carefully appraised and only the least promising ones topworked at first. Also, the superior trees should be marked to save, inasmuch as a high quality, tasty, rough variety with very thin shell may have distinct value, especially if the macadamia is to be sold as a fresh or unroasted product.

Treatment of Trees Before Topworking

If the trees are in poor vigor due to neglect or starvation, they must be fertilized, pruned, and cultivated to bring them back into good vigor before topworking is attempted.

This may require a full growing season or longer. Trees in good condition should be topped in the late fall or early spring, before active growth begins, in order to avoid excessive bleeding and to secure a full year's growth of suckers. Topping consists of removing the top of the tree 4 or 5 feet above the ground*. If branches occur below this level, they should be cut off leaving stubs 1½ or 2 feet in length. The cuts should be perpendicular to the axis of the trunk or branch so that the cut surface will be as small in area as possible. Cut surfaces probably should not exceed 3 inches in diameter.

Splitting of the trunk or branch in the topping operation not only seriously weakens the branch but makes it almost impossible to control wood-rotting organisms. Sunscald is also a serious factor to be considered after the tops are removed. A heavy coating of whitewash or tying straw or grass around the trunk and main limbs will often prevent this complication. All cut surfaces should be sterilized with dilute Bordeaux mixture and painted with a good linseed oil paint or some suitable grafting preparation. It is essential that all wounds be protected until they are entirely healed over. Later, shoots arising from the trunk and limbs will offer some protection from the sun and also will aid in healing over the cut surfaces.

During the growing season many suckers will spring up from dormant buds on the trunks and limbs. Most of these should be allowed to grow, not only to supply food materials to the roots and trunk, thus keeping them in a healthy condition, but also to prevent sunscald of the trunk and to aid in the quick healing of the cut surfaces. However, 2, 3, or 4 shoots arising at or near each of the cut surfaces should be selected and encouraged to take dominance over the rest by judicious pruning or thinning out of interfering or less favorably located shoots. Figure 7*a* illustrates the amount and type of growth that may be expected from a large vigorous tree that was topped one year previously. None of the shoots have been removed in this case.

Grafting Operations

Grafting in connection with topworking is performed at the same season and by using the same methods and

*Later tests may show that only part of the top should be removed at this time and that the rest should be removed at a later date.

(*a*) (*b*)

Figure 7—(*a*) Illustrates sucker growth 12 months after the top of the tree was cut off. (*b*) Two suckers selected as near as possible to the cut surface of a branch stub have been grafted. After the formation of a strong union the sucker will be removed at a point immediately above the graft union. Note the vigorous growth of the scion shoots.

technique as that employed in grafting nursery trees. The percentage of successful grafts at this time has proved even greater than the percentage of successful nursery grafts. The one-year-old shoots should be thinned out, leaving 2, 3, or 4 on the trunk or stub of a branch, depending on its diameter. The shoots selected should be as close as possible to the point where the top was cut off, so that they may aid in healing the cut surface. These shoots should be cut back somewhat, and their lower leaves should be trimmed off. Then the scions should be inserted into the shoots, tied and waxed, as described under the side-wedge or side-paste methods. The shoots of these trees are usually more vigorous and of greater diameter than those of a nursery seedling and consequently, larger scions may be used. In windy locations too much of the top should not be left on the shoot and the side-paste graft would be preferable in order to prevent the shoot breaking at the graft.

Figure 7*b* illustrates two well-formed and well-placed shoots on the stub of a branch. Both shoots were grafted with the side-wedge method, and both are growing. A week or so after this picture was taken, the shoots were cut back to the graft union. Note that the shoots have arisen very close to the cut. The active growth of shoots in this position will materially aid and hasten the healing of the cut surface.

Additional shoots might have been left on this stub to protect it from sunscald and otherwise to aid in maintaining the stub and trunk in a healthy growing condition. If shoots are left they need not be grafted and should be pruned back, so that they will not interfere in any way with or shade the growing grafts. Such shoots may also serve another useful purpose in that the young tender shoots arising from the scion may be tied loosely to them for support.

Subsequent Care of Topworked Trees

Eventually only one of the grafts on any one branch stub should be permitted to remain and, perhaps, only one or at most two on the main trunk. The stronger and better-formed grafts, as well as the dominant and most vigorous shoot from each of such grafts, should be encouraged to assume dominance by removing or pruning back shading or interfering shoots and branches. The secondary grafts or shoots from the trunk should not be removed entirely until

(*a*) (*b*)

Figure 8—(*a*) Illustrates a branch seriously damaged by sunscald and secondary organisms; (*b*) A method of treating branches shown in "*a*." The dead wood has been removed and the surface painted with a dry Bordeaux-linseed oil paint. Such extensive repair work is expensive and the tree is doubtless permanently weakened.

the original topping wound is entirely healed and until the favored graft has developed a large leaf surface and is capable of supporting the trunk and root system of the tree. At this time, all branches should be removed from the old seedling so that the entire top of the tree will be of the grafted variety. This may not be possible until 4 or 5 years after the topworking was started.

Wood-rotting organisms gaining entrance to the body of the tree through the large cut surfaces and through sunscald wounds present one of the major difficulties that is encountered in topworking. If such organisms gain entrance, the possibilities of rebuilding a strong thrifty tree are greatly reduced. Every precaution must be taken to avoid such damage. Immediate steps should be taken to cut out all diseased tissue when the tree becomes infected and to sterilize and paint over the healthy tissue, in order to protect it and to encourage rapid healing over of the wounded surfaces. Figure 8*a* illustrates the damage that sunscald, followed by invasion of decay organisms, may do while Figure 8*b* shows the nature and extent of corrective measures that delay may require.

No experience has yet been gained as to age of bearing and yield of topworked trees beyond observations on one or two trees at the Kona Substation. These are small nursery trees that were grafted and left in place. They are bearing a few clusters of nuts at 3 years of age after grafting. It is to be expected that older topworked trees which make strong vigorous growth, should begin bearing fruit in 3 or 4 years after grafting. Such is the case with many other fruit and nut species.